Internal Cooling in Leading- and Trailing-Edge Passages with Rotation and Buoyancy

S. Acharya and D. Nikitopoulos
Mechanical Engineering Department
Louisiana State University
Baton Rouge, LA 70803

The ongoing research deals with flow and heat transfer in rotating channels. This configuration is of interest in internal cooling of gas turbine blades. Efforts directed toward improving the performance of gas turbine engines through increased turbine inlet temperatures require a clear understanding of the flow and heat transfer mechanisms under rotational conditions, and for parameters relevant to actual gas turbine engines. These parameters include aspect ratio and shape of the coolant channel, the channel orientation relative to the rotational axis, the Reynolds number ($Re=UD_h/\nu$) , the Rotation number ($Ro=\Omega D_h/U$) and the centrifugal buoyancy parameter ($BP=Ro^2(R/D_h)(T_w-T)/T_w$). The majority of the published literature deals with square or 1:2 aspect ratio channels, and the majority of the data published is for buoyancy parameters less than 1. However, the coolant passages in turbine blades can have aspect ratios of the order of 1:4 (along the leading edge) and 4:1 along the trailing edge, and buoyancy parameters can be considerably higher than that reported in the literature. The present work will experimentally investigate heat transfer in high/low aspect ratio channels (1:4 or 4:1) with different orientations (relative to the rotational axis) for Reynolds number up to 500,000, Rotation number up to 1, and buoyancy parameter values up to 5. These measurements will be done in a rotating rig donated by UTRC, with instrumented test sections that will be fabricated or modified. Details of the velocity field, and further extensions of the above parameters (triangular leading edge cross-sections, Reynolds number up to a million, and buoyancy parameters up to 10) are being done using a validated CFD code.

CFD calculations appear to compare well with the measurements of Wagner and Johnson in a three-pass square coolant passage (smooth and with normal trips) with and without rotation. The streamwise distributions of the average Nusselt number in the three radial passages for the 1:1, 1:4, and 4:1 cases indicate that the lowest heat transfer rates are observed for the 1:4 case, while the square and 4:1 cases show comparable rates.

With rotation, both the 1:4 and 4:1 cases exhibit the behavior observed for the 1:1 case, that is, enhanced heat transfer (relative to the stationary channel) along the trailing surfaces of the radially-outward flow leg, and leading surfaces of the radially-inward flow leg. These differences are greater for the 1:4 case.